DESCRIPTION

OPTICAL HEAD AND OPTICAL DISC DRIVE INCLUDING THE OPTICAL HEAD

TECHNICAL FIELD

The present invention relates to an optical head for optically reading and/or writing data from/on an information storage medium such as an optical disc.

BACKGROUND ART

Recently, densities of optical discs have been further increased. For example, a phase change optical disc, on which preformed grooves have a pitch of 0.32 μm, information tracks also have a track pitch of 0.32 μm and a coating layer to protect its information storage layer has a thickness of 0.1 mm, is known as a typical optical disc with an increased density. To read and/or write data from/on such an optical disc, the optical head of an optical disc drive may include a light source with a wavelength of 405 nm and an objective lens

with a numerical aperture NA of 0.85, for example.

A high-density optical disc has such a narrow information track pitch that the optical head needs to perform a tracking control operation with very high precision. Accordingly, once a deviation has occurred in a tracking error signal due to the shift of the objective lens or the tilt of the optical disc, the tracking control operation can no longer be performed with the required precision, thus causing some problems. As used herein, the "deviation" of the tracking error signal refers to a gap (or distance) between the beam spot location and the center of the information track when the tracking error signal crosses the zero level.

Also, data is written on a phase change optical disc by changing the reflectance. The phase change optical disc has a narrow track pitch between adjacent information tracks. Accordingly, if the adjacent information tracks have mutually different reflectances, then the tracking error signal could not be detected accurately due to the difference. Furthermore, due to an error occurring during the

manufacturing process of optical discs, the information track pitch might be variable from one location to another. In that case, the tracking error signal could not be detected accurately, either. Then, the tracking control operation could not be carried out with sufficient precision on a high-density optical disc. For that reason, efforts for detecting the tracking error signal as accurately as possible have been carried on.

For example, PCT International Application Publication No. WO 97/15923 discloses a technique of reducing the deviation that could occur in a tracking error signal due to the shift of an objective lens and the tilt of an optical disc. Hereinafter, a configuration for realizing the technique disclosed in this document will be described.

FIG. **1(a)** shows a configuration for a conventional optical head **100**. The optical head **100** includes: a light source **101**; a lens **102** for transforming the light emitted from the light source **101** into luminous flux of parallel rays; half mirrors **103** and **106** for reflecting a portion of incoming light

and transmitting another portion of the light; an objective lens **104** for focusing the light; a focus control section **107** for performing a focus control operation by detecting the luminous flux that has been reflected from an optical disc **105**; and a light receiving section **108** for receiving the luminous flux, reflected from the optical disc **105**, at a plurality of light receiving areas.

The optical head **100** operates in the following manner. Specifically, the light emitted from the light source **101** is focused on the optical disc **105** by way of the lens **102**, half mirror **103** and objective lens **104**. A portion of the luminous flux of reflected rays, which has been reflected from the optical disc **105**, is further reflected by the half mirror **106** toward the focus control section **107**. The rest of the reflected luminous flux is transmitted through the half mirror **106** to enter the light receiving section **108**. The focus control section **107** detects a focus error signal based on the received signal and controls the distance between the objective lens **104** and the optical disc **105** with the detected signal such that the light emitted from the light source **101**

is focused on the optical disc **105** with a desired precision. On the other hand, the signal received at the light receiving section **108** is used to generate a tracking error signal. The light is focused on an information track, which extends in the direction coming out of the paper.

FIG. **1(b)** shows the cross section of the luminous flux received at the light receiving section **108**. The cross section **110** of the luminous flux is split into two by a division line **109a**, which extends parallel to the information tracks, and further split by two more division lines **109b** and **109c**, which cross the division line **109a** at right angles. In this manner, the cross section of the luminous flux is divided into eight areas **108a** through **108h**. As the optical disc **105** rotates, the beam spot of the reflected light apparently moves from the area **108a** toward the area **108g**, for example. On the other hand, the area **108i** is a light shielding area, which cuts off the incident light. The light rays falling on these areas **108a** through **108h** are detected as signals representing their respective quantities of light. If the signals detected by these areas **108a** through **108h** are identified by their

reference numerals, the tracking error signal **TE** is given by:

$$TE=(108c+108e-108d-108f)-k(108a+108g-108b-108h) \quad (1)$$

where k is a correction factor. If the objective lens **104** is moved perpendicularly to the information tracks, then the cross section **110** of the luminous flux shifts perpendicularly to the division line **109a** on the light receiving section **108**. As a result, an offset is produced in a so-called push-pull signal (108c + 108e − 108d − 108f). This offset is corrected with the signal (k(108a + 108g − 108b − 108h)). The correction factor k is defined such that the offset of the tracking error signal decreases as the objective lens **104** moves.

It should be noted that the "deviation" and "offset" of the tracking error signal are two different notions. Specifically, the "deviation" of the tracking error signal changes incessantly according to the positional relationship between the focal point of the light beam and the information storage layer and the reflectance of the information storage layer. Accordingly, the deviation cannot be minimized uniformly by using a factor such as the correction factor

described above. On the other hand, the "offset" of the tracking error signal is produced steadily in the overall signal due to the shift of the objective lens described above, for example, and can be reduced uniformly with the correction factor.

FIG. **2** schematically shows the light intensity distribution of the luminous flux **110** that has been reflected from the tilted optical disc **105**. As used herein, "tilting" means tilting a normal, which is defined perpendicularly to the optical disc **105**, parallel to the paper in FIG. **1(a)**. When the optical disc **105** tilts, the light diffracts on the information track, thus making the light intensity distribution of the reflected light non-uniform. In FIG. **2**, the hatched areas **110-1** represent the areas in which zero-order and first-order components of the luminous flux diffracted by the information track are superposed one upon the other. The remaining area **110-2** of the luminous flux **110**, other than the hatched areas **110-1**, represents an area receiving only the zero-order diffracted light, i.e., where no diffracted light components are superposed. As can be seen

from FIG. **2**, the hatched areas **110-1** are asymmetric with respect to the division line **109a**.

When the light intensity distribution is asymmetric, the light receiving section **108** cannot judge whether that state was caused by the tilt of the optical disc **105** or by a bad tracking state. If a tracking error signal is generated from such reflected light, then the tracking error signal will represent the bad tracking state all the way and therefore have a low signal precision. For that reason, the light shielding area **108i** is provided as shown in FIG. **1(b)** such that the portion of the light corresponding to the significantly asymmetric portion of the intensity distribution is not converted into a signal (i.e., not used to generate or detect a tracking error signal). In this manner, the detection errors of the tracking error signal can be reduced.

There are some optical discs on which address information and other identification information is pre-recorded as wobbles of information tracks (i.e., by way of a wobble signal). FIG. **3** is a partial enlarged view of wobbled information tracks **105-1** through **105-3** on the optical disc

105. These information tracks **105-1** through **105-3** have respective wobbles representing the information recorded there. The wobbles of the three information tracks **105-1** through **105-3** change independently of each other. The technique of detecting such a wobble signal with a push-pull signal is disclosed in Japanese Laid-Open Publication No. 7-14172, for example.

The tracking error signal to be obtained from the light reflected from the high-density optical disc **105** will be described by reference to the results of numerical simulations. Those simulations were done with the conventional optical head **100** shown in FIG. **1** under the conditions that the light had a wavelength of 405 nm, the information tracks had a track pitch of 0.32 $\mu\cdot$m and a groove depth that was one-twelfth of the wavelength, the NA was 0.85, and the objective lens had a focal length of 2 mm. It should be noted that the information track groove is a recessed groove defined between two raised information tracks. The information tracks and information track grooves are defined herein as such. However, when viewed from over the other side of the optical

disc **105**, the tracks and track grooves will be recessed and raised, respectively. Thus, the following description will be mainly focused on the "information tracks".

Hereinafter, it will be described how the tracking error signal should be affected in respective situations where the objective lens has shifted, where the optical disc is tilted, where the pitch between the information tracks is variable, and where adjacent information tracks have mutually different reflectances.

(1) Offset of tracking error signal due to the shift of objective lens:

FIG. **4** schematically shows the light intensity distribution of a luminous flux that was reflected from the high-density optical disc and detected by the light receiving section. The hatched areas represent areas where the zero-order and first-order components of the luminous flux, diffracted by the information track grooves of the optical disc **105**, were superposed one upon the other. The other non-hatched area consisted essentially of the zero-order diffracted light only (i.e., the area where no diffracted

light components were superposed). Compared with the light intensity distribution shown in FIG. **1(b)** or FIG. **2**, the gap **L** between the two hatched areas is wider and the area consisting essentially of the zero-order diffracted light is broader in the light intensity distribution shown in FIG. **4**. This is because the high-density optical disc has a narrower pitch between the information tracks.

In such a distribution, the push-pull signal has a low degree of modulation, and therefore, even if the objective lens **104** has been shifted just slightly, a non-negligible offset will be produced in the signal. Such a luminous flux is received at the respective divided areas shown in FIG. **4**. The gap between the two division lines **109b** and **109c** is approximately equal to the maximum width of the diffracted light superposed areas (i.e., the hatched areas shown in FIG. **4**) as measured along the division line **109a**. It should be noted that the light shielding area **108i** shown in FIG. **1(b)** is not provided because the offset correction is the only concern here.

FIG. **5** shows a relationship between the shift of the

objective lens **104** and the symmetry of the tracking error signal. The abscissa represents the shift of the objective lens while the ordinate represents the symmetry of the tracking error signal. The symmetry is obtained herein as the ratio of the offset voltage to the voltage amplitude. It can be seen that while the shift of the objective lens falls within the range of ±0.3 mm, good symmetry is maintained and the offset is corrected sufficiently.

(2) Non-uniform information track pitch

If the pitch between information tracks is non-uniform, then some pair of adjacent information tracks at one location on the optical disc **105** may be relatively close to each other but another pair of adjacent information tracks at another location on the optical disc **105** may be relatively distant from each other. FIG. **6** shows a model on which the leftmost one of three information tracks may be displaced. On this model, the waveform of the tracking error signal was simulated.

FIGs. **7(a)** and **7(b)** show the waveforms of the tracking error signals obtained by displacing the leftmost information

track. In this case, the information track was displaced by ±20 nm. FIG. **7(a)** shows the waveforms of push-pull signals with no offset corrected. In FIG. **7(a)**, the beam spot location (i.e., the focal point of the light beam) of zero is the center of the reference information track and corresponds to the center of the central track shown in FIG. **6** (which will be referred to herein as the "center track"). In the range where the beam spot locations are negative, signals representing the leftmost information track to be displaced in FIG. **6** appear. On the other hand, in the range where the beam spot locations are positive, signals representing the rightmost information track in FIG. **6** appear.

The three signal waveforms **114, 115** and **116** shown in FIG. **7(a)** are signals obtained by displacing the leftmost information track in three stages. More specifically, the waveform **115** is obtained by arranging the leftmost information track at the originally designed location; the waveform **114** is obtained by displacing the leftmost information track by 20 nm toward the center track; and the waveform **116** is obtained by displacing the leftmost information track by 20 nm away from

the center track. It should be noted that the rightmost track is supposed to be arranged just as originally designed. In FIG. **7(a)**, a significant offset variation is observed in the vicinity of each information track displaced from the original location (i.e., near the left-hand-side peak of the waveform), which shows the effects of the non-uniform information track pitch.

FIG. **7(b)** shows the waveforms of tracking error signals of which the offsets are corrected. The offsets are corrected with an objective lens position signal. As in FIG. **7(a)**, the three waveforms **117**, **118** and **119** shown in FIG. **7(b)** are signals obtained by displacing the leftmost information track in three stages. More specifically, the waveform **118** is obtained by arranging the leftmost information track at the originally designed location; the waveform **117** is obtained by displacing the leftmost information track by 20 nm toward the center track; and the waveform **119** is obtained by displacing the leftmost information track by 20 nm away from the center track. Compared with FIG. **7(a)**, the effects of the offset variation on the signal waveforms are reduced significantly in

FIG. **7(b)**. This means that the offset variation caused by the non-uniformity of information track pitches is corrected by the offset correcting means described above. It should be noted that the correction factor used in the calculations for FIG. **7(b)** has the same value as the correction factor for correcting the offset of the objective lens as described above.

(3) Tilt of the optical disc:

Next, it will be considered whether or not the deviation of the tracking error signal due to the tilt of the optical disc **105** can be reduced when the light shielding area **108i** (see FIG. **1(b)**) is provided for the light receiving section **108**. It should be noted that the "deviation" of the tracking error signal refers to the gap (or distance) between the beam spot location and the center of the information track when the tracking error signal crosses the zero level as described above.

FIG. **8** shows how the waveform of the tracking error signal changes when the width of the light shielding area **108i** is changed in the direction in which the division line **109a**

(see FIG. **1(b)**) extends. The abscissa represents the beam spot location, which is defined with respect to the center of the information track as the origin, while the ordinate represents the signal level. The width of the light shielding area **108i** was changed in three steps, thereby obtaining three waveforms **111, 112** and **113**. Specifically, the waveform **111** was obtained when the width of the light shielding area **108i** was zero (i.e., when no light shielding area **108i** was provided), the waveform **112** was obtained when the width of the light shielding area **108i** was 20% of the diameter of the luminous flux, and the waveform **113** was obtained when the width of the light shielding area **108i** was 35% of the diameter of the luminous flux. The coating layer of the optical disc **105** had a thickness of 100 μm and the disc had a tilt of 0.6 degrees.

As can be seen from FIG. **8**, at the zero beam spot location, the signal levels should have been equal to zero but the actual signal levels decreased below the zero level and the magnitudes of the deviations were in the order of the waveforms **111, 112** and **113**. That is to say, the greater the

width of the light shielding area **108i**, the greater the deviation of the tracking error signal. Consequently, as for high-density optical discs to be developed and put on the market in the near future, the deviation of the tracking error signal cannot be reduced by the conventional technique.

(4) Offset produced in the tracking error signal on the boundary between information tracks with different reflectances:

FIG. **9** shows the cross sections of three information tracks. Among the tracks shown in FIG. **9**, the center track and another information track on the right-hand side are supposed to have a reflectance of 1 and be unrecorded tracks. On the other hand, the other hatched information track on the left-hand side is supposed to have a reflectance of 0.5 and be a recorded track. The optical disc **105** is supposed to have multiple sets of these tracks that are arranged periodically.

FIG. **10(a)** shows the waveforms of push-pull signals of which the offsets are not corrected. Among the three signal waveforms shown in FIG. **10(a)**, the bold curve represents the waveform of a push-pull signal at the focal point of the beam

spot, the solid curve represents the waveform of a push-pull signal when the focal point of the beam spot is shifted by +0.2 μm, and the dashed curve represents the waveform of a push-pull signal when the focal point of the beam spot is shifted by -0.2 μm. The focal point of the beam spot is "shifted" perpendicularly to the optical disc **105**, i.e., in the direction in which the light beam is radiated toward the optical disc **105**. In this case, the positive direction refers to shifting the focal point toward the optical head as viewed from the optical disc **105**, while the negative direction refers to shifting the focal point in the opposite direction. In these waveforms, a significant offset variation due to the difference in reflectance between adjacent information tracks and the change of that offset variation with the focus shift of the beam spot are recognized.

Thus, the waveforms of offset-corrected tracking error signals were calculated using the same correction factor as that used to correct the offset resulting from the shift of the objective lens. FIG. **10(b)** shows the waveforms of tracking error signals of which the offsets are corrected.

Among the three signal waveforms shown in FIG. **10(b)**, the bold curve represents the waveform of a push-pull signal at the focal point of the beam spot, the solid curve represents the waveform of a push-pull signal when the focal point of the beam spot is shifted by +0.2 μm, and the dashed curve represents the waveform of a push-pull signal when the focal point of the beam spot is shifted by -0.2 μm. It can be seen that the offset variations of the three waveforms shown in FIG. **10(b)** are much less remarkable than those shown in FIG. **10(a)**.

However, around the beam spot locations of 0 μm and +0.32 μm, the offset variation changes with the focal point of the beam spot and the three waveforms cross the zero level at mutually different locations. In addition, the magnitude of change of the offset variation with the focal point of the beam spot is not constant among the three information tracks. Accordingly, even if the correction factor for the offset correction is changed, the deviation of the tracking error cannot always be reduced for every information track.

To sum up, the above-mentioned combination of conditions

for a high-density optical disc has no effects of reducing the deviation of the tracking error signal resulting from the tilt of the optical disc as described for (3) and cannot correct sufficiently the offset variation produced in the tracking error signal on the boundary between information tracks with different reflectances (or the offset variation caused by the focus shift of the beam spot, in particular) as described for (4).

Furthermore, in an optical disc with wobbled information tracks (see FIG. **3**), the gap between the central information track and its adjacent information track changes with this wobble. As already described with reference to FIGs. **7(a)** and **7(b)**, the push-pull signal is easily affected by the adjacent information track. The wobble signal of one information track may be represented by the distance from its adjacent information track. Accordingly, if the wobble signal is detected with the push-pull signal to be easily affected by the adjacent information track, then crosstalk will increase between the wobble signals of the two adjacent information tracks.

DISCLOSURE OF INVENTION

An object of the present invention is to get a tracking control done exactly on the center of a target information track on an optical disc. Another object of the present invention is to detect a wobble signal from an optical disc, on which information is recorded as wobbles, while minimizing a crosstalk phenomenon to be caused between the wobble signals of two adjacent information tracks.

An optical head according to the present invention is used to read and/or write data from/on a storage medium having at least two tracks with mutually different reflectances. The optical head includes: a light source; an objective lens for focusing light, which has been emitted from the light source, onto one of the tracks of the storage medium; and light receiving means. The light receiving means includes a plurality of light receiving areas and a non-light-receiving area. The light receiving areas receive a first type of reflected rays, where zero-order and first-

order components of the light diffracted by the track are superposed one upon the other, to generate a light quantity signal representing the quantity of light of the first type of reflected rays. The non-light-receiving area is provided between the light receiving areas so as not to receive a second type of reflected ray consisting essentially of the zero-order components. As measured in a first direction in which the light receiving areas are arranged, a gap between the light receiving areas is longer than the width of the non-light-receiving area. The optical head further includes tracking error signal generating means for generating a tracking error signal based on the light quantity signal.

As measured in a second direction perpendicular to the first direction, the length of the light receiving areas may be smaller than the width of the first type of reflected rays.

As measured in the second direction, the overall length of the light receiving areas may be greater than a luminous flux of reflected rays.

If the light source radiates light with a wavelength λ,

the objective lens has a numerical aperture NA and the track has a period T, the optical head may read and/or write data from/on a storage medium that satisfies the inequality $0.44 < \lambda/(NA \cdot T) - 1$.

The optical head may further include light splitting means for splitting a luminous flux of reflected rays into the first and second types of reflected rays.

A drive according to the present invention makes an optical head read and/or write data from/on a storage medium having at least two tracks with mutually different reflectances. The optical head includes: a light source; an objective lens for focusing light, which has been emitted from the light source, onto one of the tracks of the storage medium; and light receiving means. The light receiving means includes a plurality of light receiving areas and a non-light-receiving area. The light receiving areas receive a first type of reflected rays, where zero-order and first-order components of the light diffracted by the track are superposed one upon the other, to generate a light quantity signal representing the quantity of light of the first type of

reflected rays. The non-light-receiving area is provided between the light receiving areas so as not to receive a second type of reflected ray consisting essentially of the zero-order components. As measured in a first direction in which the light receiving areas are arranged, a gap between the light receiving areas is longer than the width of the non-light-receiving area. The optical head further includes tracking error signal generating means for generating a tracking error signal based on the light quantity signal and shifting means for changing the position of the lens parallel to the tracks responsive to a drive signal. The drive further includes: control signal generating means for generating a control signal that controls the position of the lens such that the light follows the tracks of the optical disc on the storage medium in response to the tracking error signal, and driving means for generating the drive signal that drives the shifting means in response to the control signal.

BRIEF DESCRIPTION OF DRAWINGS

FIG. **1(a)** shows a configuration for a conventional

optical head **100** and FIG. **1(b)** shows the cross section of a luminous flux received at the light receiving section **108** thereof.

FIG. **2** schematically shows the light intensity distribution of a luminous flux **110** that has been reflected from a tilted optical disc **105**.

FIG. **3** is a partial enlarged view of wobbled information tracks **105-1** through **105-3** on the optical disc **105**.

FIG. **4** schematically shows the light intensity distribution of a luminous flux that has been reflected from a high-density optical disc.

FIG. **5** is a graph showing a relationship between the shift of an objective lens **104** and the symmetry of a tracking error signal.

FIG. **6** shows a model on which the leftmost one of three information tracks may be displaced.

FIGs. **7(a)** and **7(b)** show the waveforms of tracking error signals obtained by displacing the leftmost information track.

FIG. **8** is a graph showing how the waveform of a tracking error signal changes when the width of an light shielding area

108i is changed in the direction in which the division line **109a** (see FIG. **1(b)**) extends.

FIG. **9** is a cross-sectional view of three information tracks.

FIG. **10(a)** is a graph showing the waveforms of push-pull signals of which the offsets are not corrected.

FIG. **10(b)** is a graph showing the waveforms of tracking error signals of which the offsets are corrected.

FIG. **11** is a block diagram of an optical disc drive **200** according to the present invention.

FIG. **12** shows a configuration for an optical head **220** according to a first embodiment.

FIG. **13** shows how an incoming luminous flux is split to multiple areas.

FIG. **14** is a graph showing the waveforms of TE signals when the optical disc has a tilt of 0.6 degrees.

FIG. **15** is a graph showing how the waveforms of TE signals change when only the information track pitch is changed.

FIG. **16** shows a diffraction element **19** according to a

third embodiment.

FIG. **17** is a graph showing the waveforms of TE signals obtained from information tracks with different reflectances.

FIG. **18** shows a diffraction element **22** according to a fourth embodiment.

FIG. **19** is a graph showing the waveforms of a TE signal obtained by using the diffraction grating **22** of the fourth embodiment.

FIG. **20** shows a configuration for an optical head **230** according to a fifth embodiment.

FIG. **21** shows a configuration for an optical head according to a sixth embodiment.

BEST MODE FOR CARRYING OUT THE INVENTION

Hereinafter, preferred embodiments of an optical disc drive and an optical head according to the present invention will be described with reference to the accompanying drawings.

EMBODIMENT 1

FIG. **11** shows how functional blocks of an optical disc

drive **200** according to a first embodiment of the present invention may be arranged. The optical disc drive **200** includes an optical head **220**, a control signal generating section **211**, a driver circuit **212** and a read processing section **213**. The optical disc drive **200** can read and/or write data from/on a given optical disc.

The optical head **220** is an optical system for emitting a light beam toward the optical disc **105** and receiving the light that has been reflected from the optical disc **105**. The optical head **220** reads and/or writes data from/on the optical disc **105**. Furthermore, the optical head **220** includes a signal processor for generating a tracking error signal (which will be referred to herein as a "TE signal"), a focus error (FE) signal, a read signal and other signals. The detailed configuration of the optical head **220** will be described later. The optical disc **105** is shown in FIG. **11** just for convenience sake. Thus, it should be noted that the optical disc **105** is not an integral part of the optical disc drive **200**. The optical disc **105** is supposed to be loaded into the optical disc drive **200**.

In response to the TE signal supplied from the optical head **220**, for example, the control signal generating section **211** generates a control signal for controlling the radial positional relationship between the light beam spot and the information track of the optical disc **105**. The control signal generated by the control signal generating section **211** is output to the driver circuit **212**. In response to the control signal received, the driver circuit **212** generates a drive signal and then supplies it to a tracking actuator or the transport stage (not shown) of the optical head **220**. Each of the tracking actuator and transport stage moves either an objective lens **204** only or the optical head **220** in its entirety in the radial direction of the optical disc **105**, thereby controlling the radial positional relationship between the light beam spot and the information track of the optical disc **105**. While a servo control operation such as a focus control or a tracking control is being carried out with good stability, the read processing section **213** performs a predetermined read process on the light that has been reflected from the optical disc **105**, thereby reading the data

from the optical disc **105**.

Next, the configuration of the optical head **220** will be described. FIG. **12** shows a configuration for an optical head **220** according to this embodiment. The optical head **220** includes a light source **201**, a beam splitter **202**, a collimator lens **203**, the objective lens **204**, a diffraction element **206**, a light receiving section **207**, a position signal detecting section **208**, a TE signal generating section **209** and an offset correcting section **210**.

The light source **201** may emit a violet laser beam with a wavelength of 405 nm, for example. The beam splitter **202** transmits a portion of the laser beam and reflects the rest of the light. The collimator lens **203** transforms the light coming from the light source **201** into a luminous flux of rays. The objective lens **204** converges the light beam coming from the light source **201**, thereby forming a focal point at a predetermined distance from the objective lens **204**. The diffraction element **206** receives the luminous flux that has been reflected from the optical disc **105** and then selectively passes a portion of the luminous flux through one or more

predetermined diffraction regions or cuts off the rest of the luminous flux with one or more opaque regions. To selectively pass or cut off a given luminous flux in this manner will be referred to herein as "splitting" the luminous flux. The light receiving section **207** includes a plurality of light receiving areas, each of which generates a light quantity signal representing the quantity of light received there. The position signal detecting section **208** detects the positions of the light receiving section **207** and objective lens. The offset correcting section **210** corrects the offset to be produced in the TE signal in cooperation with the TE signal generating section **209**.

Hereinafter, it will be described, along the optical path of the light, exactly how this optical head **220** carries out its processing. The light radiated from the light source **201** is transmitted through the beam splitter **202**, transformed into a luminous flux of parallel rays by the collimator lens **203**, incident onto the objective lens **204**, and then focused by the objective lens **204** onto the information storage layer of the optical disc **105**.

Thereafter, the light is reflected from the optical disc **105**, passed through the objective lens **204** and collimator lens **203** again, incident onto the beam splitter **202** and then reflected by the beam splitter **202** toward the diffraction element **206**, where the luminous flux of reflected rays is split into multiple light rays through diffraction. The light receiving section **207** includes a plurality of light receiving areas to receive the respective light rays that have been produced by the splitting action of the diffraction element **206**. That is to say, those light rays, obtained by getting the luminous flux split by the diffraction element **206**, are guided to their associated light receiving areas provided on the light receiving section **207**. In response, the respective light receiving areas generate signals representing the quantities of light received there.

From some of the light receiving areas of the light receiving section **207**, a signal for generating the TE signal is output to the TE signal generating section **209**. On the other hand, from another light receiving area of the light receiving section **207**, a signal for detecting the position

signal of the objective lens **204** is output to the position signal detecting section **208**. In response to the signal supplied from the light receiving section **207**, the TE signal generating section **209** generates the TE signal and outputs it to the offset correcting section **210**. In accordance with the signal supplied from the light receiving section **207**, the position signal detecting section **208** detects the position signal of the objective lens **204** and then passes it to the offset correcting section **210**.

The offset correcting section **210** sets the correction factor so as to decrease the offset of the TE signal and performs predetermined computation processing, thereby generating an offset-corrected TE signal. It should be noted that an offset is produced in the TE signal by changing the position of the objective lens **204**. By using this offset-corrected TE signal, the control signal generating section **211** shown in FIG. **11** generates a control signal and performs the tracking control just as intended. It should be noted that the optical head actually needs some other normal components, including a focus detecting section and a driving section to

change the position of the objective lens. However, since all of those additional components may be known ones, the description thereof will be omitted herein.

Hereinafter, it will be described in detail how the incoming luminous flux is split by the diffraction element **206**. FIG. **13** shows how the incoming luminous flux is split to multiple areas. The four areas **6a, 6b, 6e** and **6f** are areas through which light rays for detecting the objective lens position signal pass, while the two areas **6c** and **6d** are areas through which light rays for detecting the TE signal pass. The division lines **11a** through **11e** split the incoming luminous flux. Specifically, the division line **11a** splits the luminous flux into two along the information tracks. The division lines **11b** and **11c** are borders defining the objective lens position signal detecting areas and split the luminous flux perpendicularly to the information tracks. The division lines **11d** and **11e** are borders defining the TE signal detecting area and also split the luminous flux perpendicularly to the information tracks.

Furthermore, the area **Rac** between the areas **6a** and **6c**,

the area **Rbd** between the areas **6b** and **6d**, the area **Rce** between the areas **6c** and **6e**, and the area **Rdf** between the areas **6d** and **6f** are opaque areas that are designed so as not to guide the incoming light to the light receiving section **207**. These areas are provided so as to prevent the light entering these areas from being used to detect the TE signal or objective lens position signal. To achieve such an object, however, the optical head **220** may adopt a different configuration. For example, a diffraction grating may be provided in these areas to prevent the light from being guided to the light receiving areas of the light receiving section **207**. Alternatively, no features may be provided for these areas but instead the light receiving areas may be selectively removed from the light receiving section **207** on which the light rays, having passed through these areas, will be incident.

FIG. **13** illustrates the beam spot shape **12** of the luminous flux that has entered this diffraction element **206**. The hatched areas **12-1** represent the areas in which the zero-order and first-order components of the diffracted light coming from the information track are superposed one upon the

other. The remaining area **12-2** of the beam spot **12**, other than those hatched, represents an area where only the zero-order component of the diffracted light is incident.

For example, if a signal that has passed through the area **6c** of the diffraction element **206** shown in FIG. **13** and then detected at its associated light receiving area of the light receiving section **207** is identified by "6c", then the corrected TE signal is given by

$$TE = (6c - 6d) - k(6a + 6e - 6b - 6f) \qquad (2)$$

where k is the offset correction factor. The first term of Equation (2) is the uncorrected TE signal (i.e., push-pull signal) and the second term multiplied by k is the objective lens position signal. These are just as already described for the prior art.

One of the principal features of the optical head **220** of this embodiment is that in the direction parallel to the information tracks (i.e., along the division line **11a**), the gap between the division lines **11d** and **11e** is set shorter than the maximum length of the areas (i.e., the hatched areas **12-1** shown in FIG. **13**) in which the zero-order and first-order

components of the diffracted light coming from the information track are superposed one upon the other. The optical head **220** is also characterized in that the overall length of the diffraction element **206** as measured perpendicularly to the information tracks (i.e., along the division lines **11b** and **11d**) is equal to or greater than the diameter of the beam spot **12**. Thus, the deviation of the TE signal, caused by the tilt of the optical disc **105**, can be reduced. In this case, the tilt of the optical disc **105** means a tilt to be produced by rotating the plane of the optical disc **105** on the tangential line of the information tracks, i.e., a radial tilt.

Next, the TE signal to be obtained by this configuration will be described. FIG. **14** shows the waveforms of TE signals when the optical disc has a tilt of 0.6 degrees. The abscissa represents the beam spot location, which is defined with respect to the center of the information track as the origin, while the ordinate represents the signal level. The numerical calculations were carried out under the combination of conditions that adjacent information track grooves had a pitch of 0.32 μm, the light had a wavelength of 405 nm, the

objective lens had an numerical aperture of 0.85 and the coating layer had a thickness of 100 nm. Also, supposing the gap between the division lines **11b** and **11c** is identified by V1, the gap between the division lines **11d** and **11e** is identified by V2, and these values V1 and V2 are represented as ratios to the diameter of the beam spot **12**, V1 was assumed to be constant at 0.65.

FIG. **14** shows the TE signals obtained by changing the gap V2 between the division lines **11d** and **11e**. Specifically, the waveform **13** represents a situation where V2 = V1 = 0.65, the waveform **14** represents a situation where V2 = 0.43, and the waveform **15** represents a situation where V2 = 0.25. The zero-crossing points of the waveforms **13, 14** and **15** are located on the negative side (i.e., on the left-hand side of the origin), right on the origin, and on the positive side (i.e., on the right-hand side of the origin), respectively. Accordingly, under these conditions, by setting V2 equal to 0.43, the deviation of the TE signal resulting from the tilt of the optical disc **105** (i.e., the gap between the zero-crossing point of the waveform of the TE signal and the center of the

information track) can be substantially eliminated. Also, if the pitch between adjacent information track grooves and the numerical aperture change, then the best V2 value changes, too. For that reason, V2 is preferably modified according to the conditions. However, the conditions to which this embodiment is applicable are limited to the range to be described below.

Hereinafter, the range to which this embodiment is applicable will be described. As can be seen from FIG. **14**, unless this embodiment is applied with V1 set equal to V2, the zero-crossing point of the TE signal shifts to the left-hand side of the origin (as indicated by the waveform **13** in FIG. **14**). However, if this embodiment is applied with V2 decreased, then the zero-crossing point shifts rightward (as indicated by the waveforms **14** and **15** in FIG. **14**). In other words, unless the direction in which the zero-crossing point shifts due to the tilt of the optical disc **105** when this embodiment is not applied is opposite to the direction in which the zero-crossing point shifts with V2 decreased by applying this embodiment, the deviation of the TE signal resulting from the tilt of the optical disc **105** cannot be reduced.

FIG. **15** shows how the waveforms of TE signals change when V1 is set equal to V2 and when only the information track pitch is changed. Specifically, the waveform **16** is associated with an information track pitch of 0.35 μm, the waveform **17** is associated with an information track pitch of 0.33 μm, and the waveform **18** is associated with an information track pitch of 0.3 μm. The abscissa and ordinate of this graph represent the same quantities as the counterparts of FIG. **14** do. Due to the tilt of the optical disc **105**, the zero-crossing points of the waveforms shift in the negative direction as the information track pitch decreases. In the calculations shown in FIGs. **14** and **15**, the optical disc **105** is supposed to be tilted in the same direction. Thus, it can be understood that the deviation of the TE signal resulting from the tilt of the optical disc **105** can be reduced by decreasing V2 only when the zero-crossing point of the waveform is located on the negative range (i.e., only when the information track pitch is smaller than 0.33 μm).

Next, this restriction condition is generalized. The shift of the zero-crossing point of the TE signal due to the

tilt of the optical disc **105** is caused by a coma aberration to be produced when the light passes through the coating layer (not shown) of the tilted optical disc **105**. Also, this shift results from a variation in intensity distribution in the areas where the zero-order and first-order components of the diffracted light coming from the information track are superposed one upon the other. This variation in intensity distribution is determined by how those components are superposed at the edges of the luminous flux with a wave aberration. Accordingly, the shift of the zero-crossing point depends on the wavelength, information track pitch, and numerical aperture of the objective lens. Supposing the wavelength is denoted by λ, the information track pitch is T and the numerical aperture of the objective lens is NA, a quantity U is defined by

$$U=\lambda/(T\cdot NA)-1 \qquad (3)$$

This quantity U represents the ratio of the gap **W** between the right and left hatched areas shown in FIG. **13** to the diameter of the luminous flux. If the boundary conditions of the present invention and the prior art, i.e., $T=0.33\ \mu m$, NA=

0.85 and $\lambda = 405$ nm, are substituted into Equation (3), then U is 0.44. Equation (3) shows that as T is decreased, U increases. Also, according to the conditions described above, this embodiment is applicable only when adjacent information track grooves have a pitch smaller than 0.33 μm. Thus, the generalized application condition is

$$U > 0.44 \qquad (4)$$

It should be noted that if U is smaller than 0.44, then it is the application range of the prior art described above.

As described above, according to this embodiment, by detecting the TE signal from a range that is narrower than the width of the areas, where the zero-order and first-order components of the diffracted light coming from the information track are superposed one upon the other, as measured along the information track, the deviation of the TE signal resulting from the tilt of the optical disc **105** due to the tilt of the optical disc can be reduced.

In the embodiment described above, the position signal detecting section **208** is provided. However, in an optical disc drive in which the shift of the objective lens can be

sufficiently reduced to ±0.05 mm or less, for example, the same effects are also achieved even if the position signal detecting section **208** is omitted from the drive.

EMBODIMENT 2

As a second embodiment of the present invention, an optical disc satisfying the inequality

$$0.40 < \lambda/(T \cdot NA) - 1 < 0.46 \qquad (5)$$

where λ is the wavelength of light, NA is the numerical aperture of an optical head for reading and/or writing data from/on the optical disc and T is the period of information track grooves, will be considered.

In reading and/or writing data from/on such an optical disc, the optical head operates just as already described for the first embodiment, and the description thereof will be omitted herein. Instead, it will be described here why such an optical disc can minimize the deviation of the TE signal due to its own tilt.

If the boundary condition (inequality (4)) as described for the first embodiment is modified into

$$U=0.44 \tag{6}$$

then this is the condition on which the waveform **17** shown in FIG. **15** was calculated. As described above, in that case, almost no deviation is caused in the TE signal due to the tilt of the optical disc **105** even by the conventional TE signal generating method. Accordingly, an optical disc **105** substantially satisfying $U=0.44$ is preferably made. For example, supposing the wavelength is 405 nm and NA is 0.85, an optical disc, of which the information track pitch is defined somewhere between 0.326 μm and 0.340 μm, can satisfy this condition.

The waveform **13** shown in FIG. **14** represents a situation where the information track pitch **T** is 0.32 μm. On the other hand, the waveform **16** shown in FIG. **15** represents a situation where the information track pitch **T** is 0.35 μm. The tilt of the optical disc is supposed to be 0.6 degrees in both cases. The deviations of the TE signal as represented by these waveforms are far from being sufficiently small and are preferably cut down to half or less. If $T=0.32$ μm, U is 0.49. On the other hand, if $T=0.35$ μm, U is 0.36. Thus,

the conditions represented by inequality (5) were obtained by adopting intermediate values between the best U value of 0.44 represented by Equation (6) and these two U values. Those conditions substantially satisfy Equation (6).

As described above, even if the optical disc of this embodiment has a tilt of about 0.6 degrees, which is allowed for a normal optical disc, the optical disc can still reduce the deviation of the TE signal due to that tilt to a substantially negligible level.

EMBODIMENT 3

An optical head according to a third embodiment of the present invention is different from the optical head of the first embodiment only in the method of splitting the luminous flux by the light splitting means (i.e., diffraction element). Thus, the following description will be focused on this difference.

FIG. **16** shows a diffraction element **19** according to this third embodiment. An optical head according to this embodiment can be obtained by substituting this diffraction

element **19** for the diffraction element **206** shown in FIG. **12**. The diffraction element **19** splits the luminous flux by areas **19a** through **19g**, which are defined by division lines **20a, 20b** and **20c**. FIG. **16** shows the beam spot shape **21** of the luminous flux that has entered this diffraction element **19**.

The respective areas for the split luminous flux will be further described. The four areas **19a, 19b, 19e** and **19f** are areas through which light rays for detecting the objective lens position signal pass. The two areas **19c** and **19d** pass the light rays for detecting the TE signal. The area **19g** with horizontal hatching may be a diffraction element for diffracting the light ray and is designed such that even the reflected light ray that has entered this area **19g** will not reach an area of the light receiving section **207** for generating the TE signal. The areas with oblique hatching represent the areas where the zero-order and first-order components of the diffracted light coming from the information track are superposed one upon the other.

Hereinafter, the relationship between the widths **W1** and **W2** of the areas shown in FIG. **16** will be described. More

specifically, the width **W1** represents the gap between the areas where the two types of components of the diffracted light coming from the information track are superposed one upon the other. On the other hand, the width **W2** corresponds to the width of the area where no TE signal should be detected. The light rays that have been split to the respective detecting areas **19a** through **19f** are then guided to, and received at, the light receiving section **207**. For example, if a signal that has passed through any area of the diffraction element **19** shown in FIG. **16** and then detected at its associated light receiving area of the light receiving section **207** is identified by the reference numeral given to that area of the diffraction element **19**, then the corrected TE signal is given by

$$TE=(19c-19d)-k(19a+19e-19b-19f) \qquad (7)$$

where k is the offset correction factor.

The first term of Equation (7) is the uncorrected TE signal (i.e., push-pull signal) and the second term, multiplied by the offset correction factor k, is the objective lens position signal.

One of the features of this embodiment is to provide the TE signal non-detecting area **19g** approximately at the center of the incoming luminous flux and between the two areas where the zero-order and first-order components of the diffracted light coming from the information track are superposed one upon the other. Thus, the offset to be produced in the TE signal when adjacent information tracks have mutually different reflectances can be reduced.

Hereinafter, the features of this embodiment will be described in further detail. FIG. **17** shows the waveforms of TE signals obtained from multiple information tracks with different reflectances. In this case, the ratio of the width **W2** of the TE signal non-detecting area **19g** to the diameter of the luminous flux **20** is supposed to be 0.36. The other calculation conditions are identical with those already described with reference to FIG. **10**. The information tracks with different reflectances are shown in FIG. **9**, for example.

Among the three waveforms shown in FIG. **17**, the bold curve represents a signal waveform at the focal point of the beam spot, the solid curve represents a waveform when the

focal point of the beam spot is shifted by +0.2 μm, and the dashed curve represents a waveform when the focal point of the beam spot is shifted by -0.2 μm. Compared with the waveforms shown in FIG. **10(b)**, the respective waveforms shown in FIG. **17** have much closer zero-crossing points in the vicinity of the respective centers of the information tracks (i.e., at the location of 0 μm and the locations of $\pm$0.32 μm on the axis of abscissas). Thus, the deviation of the TE signal has been significantly reduced with respect to any focus shifting.

Next, it will be described why the deviation of the TE signal could be reduced. If a beam spot crosses multiple information tracks with various reflectances, then a diffraction pattern, representing not only the periodicity of any information track but also the periodicity of that reflectance variation, will appear in the cross section of the luminous flux reflected from the optical disc. Supposing one of the three information tracks has a lower reflectance as shown in FIG. **9**, the period of the fundamental wave representing the reflectance variation will be three times as long as the information track pitch and the second- and third-

order components of the Fourier series will be 1.5 times as long as, and 1.0 time as long as, the information track pitch, respectively. Diffracted light that has come from a structure with a period greater than the information track pitch has a small diffraction angle. In that case, the diffracted light will appear at the center of the luminous flux, too. However, by using the diffraction element **19** of this embodiment, the TE signal is generated with the center portion of the luminous flux filtered out through the area **19g**. Accordingly, even if the intensity distribution has varied in that center portion, its effect is much smaller than the situation where the TE signal is generated with that center portion of the luminous flux used. Consequently, the deviation of the TE signal can be reduced without varying the offset of the TE signal.

It should be noted that the widths **W1** and **W2** of the areas shown in FIG. **16** preferably satisfy the inequality $W1 > W2$. This is because if $W1 \leqq W2$, then the light rays represented by the oblique hatching in FIG. **16** would overlap with the TE signal non-detecting area **19g**. In that case, if the TE signal were detected based on the variation in intensity distribution

of those hatched areas, then the resultant accuracy would decrease. Particularly if the diffraction element **19** is fixed to the optical head, the luminous flux shifts as the objective lens **204** is moved. As a result, the light rays in the hatched areas further expand toward the TE signal non-detecting area **19g**, thus making the TE signal even less accurate.

According to the embodiment described above, by providing the TE signal non-detecting area at the center of the luminous flux, the offset to be produced in the TE signal on the boundary between multiple information tracks with mutually different reflectances can be reduced.

EMBODIMENT 4

An optical head according to a fourth embodiment of the present invention is different from the optical head of the first embodiment only in the method of splitting the luminous flux by the light splitting means (i.e., diffraction element). Thus, the following description will be focused on this difference.

FIG. **18** shows a diffraction element **22** according to this

fourth embodiment. An optical head according to this embodiment can be obtained by substituting this diffraction element **22** for the diffraction element **206** shown in FIG. **12**. The diffraction element **22** splits the respective light rays to areas **22a** through **22g**, which are defined by division lines **23a** through **23e**. FIG. **18** shows the beam spot shape **24** of the luminous flux that has entered this diffraction element **19**.

The respective areas for the split luminous flux will be further described. The four areas **22a, 22b, 22e** and **22f** pass through the light rays which are used for detecting the objective lens position signal. The two areas **22c** and **22d** pass the light rays for detecting the TE signal. The area **22g** with horizontal hatching may be a diffraction element for diffracting the light ray and is designed such that even the reflected light ray that has entered this area **22g** will not reach an area of the light receiving section **207** for generating the TE signal.

Furthermore, the area between the areas **22a** and **22c**, the area between the areas **22b** and **22d**, the area between the areas **22c** and **22e**, and the area between the areas **22d** and **22f** are

opaque areas that are designed so as not to guide the incoming light to the light receiving section **207**. These areas are provided so as to prevent the light entering these areas from being used to detect the TE signal or objective lens position signal. As long as this object is achieved, the diffraction element **22** may adopt a different configuration. For example, a diffraction grating may be provided in these areas to prevent the light from being guided to the light receiving areas of the light receiving section **207**. Alternatively, no features may be provided for these areas but instead the light receiving areas may be selectively removed from the light receiving section **207** on which the light rays, having passed through these areas, will be incident.

Also, in FIG. **18**, the areas with oblique hatching represent the areas where the zero-order and first-order components of the diffracted light coming from the information track are superposed one upon the other. Furthermore, in FIG. **18**, W1 represents the gap between the areas where the two types of components of the diffracted light coming from the information track are superposed one

upon the other. On the other hand, W2 represents the width of the TE signal non-detecting area **22g**. The light rays that have been split to the respective detecting areas **22a** through **22f** are then guided to, and received at, the light receiving section **207**. For example, if a signal that has passed through any area of the diffraction element **22** shown in FIG. **18** and then detected at its associated light receiving area of the light receiving section **207** is identified by the reference numeral given to that area of the diffraction element **22**, then the corrected TE signal is given by

$$TE = (22c - 22d) - k(22a + 22e - 22b - 22f) \quad (8)$$

where k is the offset correction factor.

The first term of Equation (8) is the uncorrected TE signal (i.e., push-pull signal) and the second term, multiplied by the offset correction factor k, is the objective lens position signal.

One of the features of this embodiment is to set the width of the TE signal generating areas **22c** and **22d** along the information tracks (i.e., as measured along the division line **23a**) shorter than that of the obliquely hatched areas in the

same direction and to provide the TE signal non-detecting area **22g** approximately at the center of the incoming luminous flux. Thus, both the deviation of the TE signal due to the tilt of the optical disc and the offset to be produced in the TE signal on the boundary between information tracks with mutually different reflectances can be reduced at the same time. This is because the diffraction element **22** of this embodiment includes not only areas corresponding to the areas **Rac, Rbd, Rce** and **Rdf** of the diffraction grating **206** of the first embodiment but also an area **22g** corresponding to the TE signal non-detecting area **19g** of the diffraction element **19** of the third embodiment. Hereinafter, it will be described how these two effects are achieved at the same time even if those two configurations are combined.

First, the effect of reducing the deviation of the TE signal due to the tilt of the optical disc is determined by the ratio of the width of the TE signal detecting areas to that of the obliquely hatched areas shown in FIG. **18**. Accordingly, even if the area **22g**, not including the obliquely hatched areas, is provided, that effect can be clearly

maintained. Next, it will be considered how the TE signal changes when the width of the areas **22c** and **22d** is decreased along the division line **23a** and if the area **22g** is further provided. FIG. **19** shows the waveforms of TE signals obtained by using the diffraction grating **22** of this embodiment. The calculations were done under the same conditions as FIG. **17** except that the ratio of the gap between the division lines **23d** and **23e** to the diameter of the luminous flux and the ratio of the width **W2** to the diameter of the luminous flux were both 0.36. These waveforms exhibit good characteristics in which the zero-crossing points hardly shifted due to the focus shifting in the vicinity of the respective centers of information tracks. That is to say, even if the areas corresponding to the areas **Rac, Rbd, Rce** and **Rdf** of the diffraction grating **206** of the first embodiment and the area **22g** corresponding to the TE signal non-detecting area **19g** of the diffraction grating **19** of the third embodiment are provided in combination, the effects of the respective diffraction gratings of these two embodiments can be achieved at the same time.

Thus, according to this embodiment, the deviation of the TE signal due to the tilt of the optical disc **105** and the offset to be produced in the TE signal on the boundary between the information tracks with different reflectances can be both reduced.

EMBODIMENT 5

FIG. **20** shows a configuration for an optical head **230** according to a fifth embodiment of the present invention. The optical head **230** includes the light source **201**, a polarization beam splitter **225**, the collimator lens **203**, a polarizing diffraction element **226**, a quarter-wave plate **227**, the objective lens **204**, a holder **228**, the TE signal generating section **209**, the offset correcting section **210** and a distribution variation detecting section **229**. In the optical head **230** of this embodiment, any component having the same function as the counterpart of the optical head **220** of the first embodiment is identified by the same reference numeral and the description thereof will be omitted herein.

The polarizing diffraction element **226** is a diffraction

element, of which the diffraction efficiency changes with the polarization direction, and functions as the light splitting means. The holder **228** holds the polarizing diffraction element **226**, quarter-wave plate **27** and objective lens **4** together. The distribution variation detecting section **229** detects a variation in the light intensity distribution of the luminous flux that has been reflected from the optical disc **105**.

The light radiated from the light source **201** is incident as a P-polarized light ray onto the polarization beam splitter **225** and transmitted through the splitter **225**. Next, the light is transformed by the collimator lens **203** into a luminous flux of parallel rays, which is incident onto, and transmitted as it is through, the polarizing diffraction element **226** so as to enter the quarter-wave plate **227**. Thereafter, the light that has passed through the quarter-wave plate **227** is transformed into a circularly polarized light ray, which is incident on, and focused on the information storage layer of the optical disc **105** by, the objective lens **204**.

The light that has been reflected from the optical disc **105** passes through the objective lens **204** again and enters the quarter-wave plate **227**. After having passed through the quarter-wave plate **227**, the light is transformed into linearly polarized light, of which the polarization direction is perpendicular to that of the P-polarized accessing light and which enters the polarizing diffraction element **226** next. The light that has entered the polarizing diffraction element **226** is diffracted this time almost entirely because its polarization direction is perpendicular to that of the accessing polarized light. The light is split by the polarizing diffraction element **226** into multiple light rays, which are then incident onto the polarization beam splitter **225** by way of the collimator lens **203**. These polarized light rays are S-polarized, and therefore, are all reflected toward the light receiving section **207**.

The light rays, which have been produced by getting the polarized light split by the polarizing diffraction element **226**, are detected at the light receiving section **207** and then supplied as signal for generating a TE signal to the TE

signal generating section **209**. On the other hand, another signal, which has been divided by the polarizing diffraction element **226** and detected at the light receiving section **207** so as to be used for detecting a light intensity distribution variation signal, is supplied to the light intensity distribution variation signal detecting section **229**.

The two signals, detected by these TE signal generating section **209** and distribution variation signal detecting section **229**, are both supplied to the offset correcting section **210**. The offset correcting section **210** defines the correction factor so as to reduce the offset to be produced in the TE signal due to a variation in the light intensity distribution of the detected luminous flux (i.e., the luminous flux that has been reflected from the optical disc and incident on the polarizing diffraction element **226**). By performing predetermined computation processing, the offset correcting section **210** generates an offset-corrected TE signal. By using this offset-corrected TE signal, a tracking control operation is carried out. The polarizing diffraction element **226** may split the luminous flux by the same method as

the diffraction element **206** shown in FIG. **13**. For example, referring to FIG. **13**, the four areas **6a, 6b, 6e** and **6f** may be used as areas to pass the light rays for detecting a variation in the light intensity distribution of the luminous flux, while the two areas **6c** and **6d** may be used as areas to pass the light rays for detecting the TE signal.

In this embodiment, the objective lens **4** and the polarizing diffraction element **226** functioning as the light splitting means are held together by the holder **228**. Accordingly, even during the tracking control operation, these members **204** and **226** are arranged so as to move together. In this arrangement, even if the objective lens **204** has shifted, the location of the detected luminous flux never changes with respect to the polarizing diffraction element **226**. Thus, by using the light rays that have passed through the areas **6a** through **6f**, the variation in information track pitch and the variation in the light intensity distribution of the detected luminous flux on the boundary between information tracks with different reflectances can be detected. Accordingly, the offset correction factor can be

defined so as to correct the variation in information track pitch and the variation in offset on the boundary between information tracks with different reflectances without taking the offset of the TE signal due to the shift of the objective lens into account. Consequently, the tracking error caused by these factors can be further reduced.

Also, if the polarizing diffraction element **226** splits the reflected light as shown in FIG. **16**, the location of the detected luminous flux never moves, and the width **W2** of the TE signal non-detecting area **19g** can be substantially equalized with the width **W1** shown in FIG. **16**. Then, more factors causing the offset variation due to the focus shifting on the boundary between information tracks with different reflectances can be eliminated and the resultant offset in the TE signal can be further reduced.

Thus, according to the embodiment described above, by arranging the light splitting means to move together with the objective lens and by making the light splitting means split the light just like the counterpart of the third or fourth embodiment described above, the offset correction factor can

be defined with a higher priority given to reducing the variation in information track pitch and the offset variation to be produced in the TE signal when adjacent information tracks have mutually different reflectances. Consequently, the resultant offset of the TE signal can be further reduced.

EMBODIMENT 6

FIG. **21** shows a configuration for an optical head according to a sixth embodiment of the present invention. The optical head of this embodiment is obtained by adding a wobble signal detecting section **240** to the optical head **220** (see FIG. **12**) of the first embodiment described above. Thus, the following description will be focused on the configuration and operation involved with the wobble signal detecting section **240**. The other configuration and operation are the same as those of the optical head **220** of the first embodiment and the description thereof will be omitted herein.

First, it will be described what signals pass where before a wobble signal is detected. In FIG. **21**, the respective light quantity signals, detected by the light

receiving section **207**, are passed to the position signal detecting section **208** and TE signal generating section **209**. The position signal detecting section **208** detects the objective lens position signal, while the TE signal generating section **209** detects the TE signal. Next, these two signals are supplied to the offset correcting section **210** and subjected to a predetermined computation using an offset correction factor **k1**, thereby obtaining a corrected TE signal. Following the notation of the first embodiment, the TE signal is given by

$$TE = 6c - 6d - k1(6a + 6e - 6b - 6f) \quad (9)$$

The objective lens position signal and TE signal are also passed from the position signal detecting section **208** and TE signal generating section **9** to the wobble signal detecting section. These two signals, introduced to the wobble signal detecting section **240**, are subjected to a predetermined computation using another correction coefficient **k2**, thereby obtaining a wobble signal **WTE**. The address information and other identification information are detected using this

wobble signal **WTE**. Following the notation of the first embodiment again, the wobble signal **WTE** is given by

$$WTE=(6c-6d)-k2(6a+6e-6b-6f) \quad (10)$$

In this case, the offset correction factor **k1** is defined so as to minimize the offset of the TE signal waveform due to the shift of the objective lens **204** by monitoring the waveform of the TE signal generated when the beam spot crosses the information tracks while no tracking control is being carried out. On the other hand, the offset correction factor **k2** is defined so as to minimize the wobble signal offset variation (i.e., an envelope variation at lower frequencies than the wobble signal frequency) to be observed in the wobble signal **WTE** while the tracking control is being carried out.

The features of the wobble signal **WTE** that has been corrected with the objective lens position signal will be described with reference to FIG. **7(b)**. According to the graph shown in FIG. **7(b)**, even if adjacent information tracks are displaced by about ±0.02 μm in the vicinity of the location of -0.32 μm, the three waveforms **117, 118** and **119** still

intersect each other at the origin and in the vicinity of the location of +0.32 μm and no variation is observed in the TE signal. That is to say, the wobble signal **WTE** represented by Equation (10) is unlikely to be affected by the displacements of adjacent information tracks. The wobble signal of an adjacent information track represents the displacement of an information track that is adjacent to a given information track. Accordingly, if the signal shown in Fig. 7(b) is unlikely to be affected by the displacement, then the wobble signal **WTE** should cause little crosstalk. Also, the crosstalk of the wobble signal appears as the offset variation of the wobble signal being monitored. Thus, to reduce the crosstalk, it is very effective to define the offset correction factor **k2** so as to minimize the offset variation.

Thus, according to this embodiment, the crosstalk of the wobble signal can be reduced, and therefore, an address can be detected accurately enough even from a high-density optical disc with a narrow information track groove pitch.

The optical head of this embodiment is supposed to use

the configuration of the optical head of the first embodiment. However, the present invention is in no way limited to this specific embodiment. Instead, this embodiment is also applicable to the optical head of the third, fourth or fifth embodiment described above or even to the conventional optical head described above. Furthermore, this embodiment is applicable for use in any other optical head as long as the optical head has means for detecting the objective lens position signal or light intensity distribution variation signal by splitting a given luminous flux to multiple surrounding areas along the information tracks.

In the foregoing description, the light transmitting and cut-off areas shown in FIG. **13**, **16** or **18** are supposed to belong to a diffraction element. Alternatively, those areas illustrated in any of these drawings may also be seen as illustrating light receiving areas and non-receiving areas of the light receiving section. This is because if there are light transmitting and cut-off areas in the diffraction element, then the light receiving section should have associated light receiving areas and non-receiving areas.

Accordingly, the light receiving function or non-receiving function (i.e., function of not using the light received) as described with reference to FIGs. **13, 16** and **18** may be provided for respective areas of the light receiving section, not the diffraction element.

INDUSTRIAL APPLICABILITY

An optical head according to the present invention can reduce not only the deviation of a TE signal due to the tilt of a given optical disc but also an offset to be produced in the TE signal on the boundary between information tracks with different reflectances. Thus, an optical disc drive, including such an optical head, can perform a tracking control accurately enough on the information tracks of the given optical disc.